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Materiel Test Procedure 5-2-503
White Sands Missile Range

U. S. ARMY TEST AND EVALUATION COMMAND
COMMON ENGINEERING TEST PROCEDURE

RESTRAINED FIRING TEST PROCEDURES

1. OBJECTIVE

The objective of this procedure is to determine missile operation and integrity when firing is conducted with the missile allowed to vibrate freely.

2. BACKGROUND

Restrained firing tests are conducted to measure the performance of a missile, its guidance system functioning characteristics, and its structural response characteristics when the missile is allowed maximum freedom to vibrate during the motor firing while being restrained in a manner comparable to its aerodynamic load profile. The restrained firing test is not primarily a propulsion test.

A comparison between restrained and "live" firings is given in Appendix A.

3. REQUIRED EQUIPMENT

a. Restrained Firing Facility as described in Appendix B
b. Firing Test Facility as described in Appendix C *
c. Firing and/or Control Console for the Missile System Under Test
d. Instrumentation as described in Appendix D
e. Motor Inspection Equipment as described in MTP 5-2-500
f. Cleaning, Flushing and Preserving Equipment, for liquid propellant motor systems, as described in MTP 5-2-501
g. Transducers, Carrier Systems, and Recorders, as required
h. Applicable Data Reduction and Conversion Equipment
i. Motion Picture Cameras and Film:
   (1) 64-128 frames per second
   (2) 1000 frames per second
j. Flight Simulator Computer

4. REFERENCES

A. Den Hartog, J. P. Mechanical Vibration, McGraw Hill Book Company, New York 1947
B. Bievlein, J. A. and Scheller, K., Methods of Measuring Thrust, American Rocket Society, Volume 23, May-June, 1953

* The facilities described are those required for static propulsion tests and components. They are usually required for any firing test.

C. Abramson, B. N., and Brandwein, D. S., The 350,000 lb. Rocket Test Stand at Lake Denmark, New Jersey, Jet Propulsion, Volume 24, September-October 1954

D. Cheng, Sin-I and Crocco, Luigi, High Frequency Combustion Instability in Rocket Motor with Concentrated Combustion, American Rocket Society, Volume 22, September-October 1952

E. Eliss, I., and Gordon, R., Longitudinal Vibration of Gas at Ambient Pressure in a Rocket Thrust Chamber, American Rocket Society, Volume 22, September-October 1952

F. Instrumentation of Rockets and Missiles, Instruments and Automation, Volume 27, April 4, 1954

G. Rocket Test Cantilever Concreting Needs More Massive Timber Tower Support, Engineering News and Records, Volume 157, July 1956

H. Rose, B.I.J., Rocket Test Sled Challenge, Astronautics, Volume 5, March 1960

I. MTP 5-2-500 Tests of Solid Propellant Systems

J. MTP 5-2-501 Tests of Liquid Propellant Systems

K. MTP 5-2-504 Structural Testing for Non-Oscillating Steady State and Transient Loads

L. MTP 5-2-506 Shock Test Procedures

M. MTP 5-2-507 Vibration Test Procedures

N. MTP 5-2-508 Acoustic Test Procedures

P. MTP 5-2-524 Missileborne Guidance & Control Subsystem Test

Q. MTP 5-2-583 Low Temperature Tests

R. MTP 5-2-594 High Temperature Tests

S. MTP 5-2-602 Equipment Safety

T. MTP 5-2-604 Structural Data Analysis Methods

U. MTP 5-2-612 Aerodynamic Load Tests

V. MTP 5-2-587 Photostress Method of Structural Data Acquisition

5. SCOPE

5.1 SUMMARY

Since a missile firing test is unique for each type of motor (solid or liquid propellant), firing facility and specific purpose of performing the test, considerations and procedures are intentionally made general to provide tests that are applicable to a variety of missile motors. Specific details that apply to the restrained firing of a particular motor are contained in the applicable specification, along with the physical characteristics and performance requirements of the motor. A general coverage of testing techniques, instrumentation and facilities, and interpretation of data are included in this MTP. The following tests are described:

a. Inspection Tests - Inspection procedures to be performed prior to mounting the motor for a restrained firing check.

b. Aerodynamic Load Tests - Tests which determine the proper method of suspension for a missile when preparing for restrained firing tests.

c. Restrained Firing Tests - A description of the general procedure for conducting restrained firing tests.

d. Post-Firing Operations

5.2 LIMITATIONS

None

6. PROCEDURES

6.1 PREPARATION FOR TEST

6.1.1 General

a. Personnel shall review all available pertinent manufacturers instructions and/or specifications for the system to be tested, determine the test facilities required, and select the required test equipment.

b. The operator of the test equipment shall be familiar with the equipment, and shall comply with the pertinent operating instructions.

c. Assure that a log folder is prepared for each missile system to retain a history of the system under test.

d. Assure that the test facility complies with the safety requirements of MTP 5-2-602.

e. Reports of previous static and restrained firing shall be available, if possible.

6.1.2 Inspection

6.1.2.1 Solid Propellant Motors

Solid propellant motors shall be subject to the motor inspection procedures conducted during the performance of MTP 5-2-500 and shall be subject to the following:

a. Weigh the motor and record its weight

b. Measure and record the nozzle throat diameter at a minimum of three locations 120° apart

6.1.2.2 Liquid Propellant Motors

Liquid propellant motors shall be subject to the prefiring operations and cleaning and purging procedures conducted during the performance of MTP 5-2-501.

6.1.3 Aerodynamic Load Tests

Assemble the complete missile system (rocket motor, electronics package, guidance and control system, etc.) and determine the missile system aerodynamic profile as described in MTP 5-2-612.

6.1.4 Instrumentation

Data shall be recorded on magnetic tape, oscillograph, and strip-chart records depending upon the frequency response and accuracy specifi-

cations of required data.

Selection of the required transducers, carrier systems, recorders, conversion and reduction equipment shall be determined by the individual specifications and test requirements.

Appendix D describes the method used to obtain the various information.

6.2 TEST CONDUCT

6.2.1 Preparation for Firing

a. Mount the complete test missile on the applicable restrained firing test stand as described in Appendix B.

b. Preload the restraining system to 200 percent of the expected maximum thrust to verify the structural integrity of the system. Remove the load.

c. Prepare instrumentation as described in Appendix D.

d. Connect, as applicable, the propellant, gas, instrument, electrical and simulating systems.

NOTE: Exercise extreme caution when connecting the test facility to the motor, ensuring that all lines are flexible so that all movement (thrust, yaw, pitch, roll) is unhampered.

e. Accomplish a complete check on all mechanical, pneumatic, and electrical systems between the missile and the instrument and control room (automatic control console).

NOTE: For liquid propellant motors:

1. Charge the system with propellants up to the main valves
2. Pressurize tanks

f. Prepare motion picture cameras to obtain complete camera coverage during firing operations.

g. Prepare the missile system, as described in MTP 5-2-587 for photostress measurements to determine structural stresses and strains.

h. Preload the restraining system from 10 to 30 percent of the expected maximum thrust.

NOTE: This will stabilize the missile system at low thrust and tend to regulate the movement ofthe missile.

i. Clear all personnel not required for checking and installing the igniter or making final regulator settings to the control center.

j. Insure the correct, short, countdown program is programmed into the automatic control console.

k. Insure the correct program is programmed into the flight simulator computer when guidance and control system tests are being run.

l. Insure adequate manual control in the event of a malfunction.
m. Clear the firing area of all personnel.

At the discretion of the test director, when applicable, the guidance and control system shall be subjected to the applicable portions of MTP 5-2-524.

6.2.2 Firing Operations

6.2.2.1 Ambient Firing Tests

a. Commence countdown
b. Commence camera coverage
c. Record the following during the firing operation:

* (1) Solid propellant motor requirements as described in MTP 5-2-500
* (2) Liquid propellant motor requirements as described in MTP 5-2-501
(3) Guidance and control system requirements as described in MTP 5-2-524.

6.2.2.2 Low Temperature Tests

The missile system shall be subject to the applicable portions of MTP 5-2-583 obtaining data as required in paragraph 6.2.2.1 above.

6.2.2.3 High Temperature Tests

The missile system shall be subject to the applicable portions of MTP 5-2-594 obtaining data as required in paragraph 6.2.2.1 above.

6.2.3 Post Firing Operations

a. Purge the flow system of liquid propellant motors immediately after firing.
b. The guidance and control system shall be subject to the procedures of paragraph 6.2.1.k and/or paragraph 6.2.2.1.c(3), when applicable, at the discretion of the test director.
c. Remove the test missile from the firing stand and subject it to visual and/or X-ray inspection to determine if any physical damage had occurred to the missile.
d. Determine the strain to which the missile skin was subjected during firing using the applicable procedures of MTP 5-2-587.
e. Liquid propellant motors shall be purged, cleaned and stored as described in the Post Firing Operation procedures of MTP 5-2-501.
f. Solid propellant motors shall be subject to the following:

* Except that propulsion system thrust is not measured as in static firings.

(1) Weigh the motor and record its weight
(2) Measure and record the nozzle throat diameter at a minimum of three locations 120° apart (see paragraph 6.1.2.1.b)

6.2.3.1 Failure Detection

In the event of a failure, see Appendix E, the missile system and its subsystems shall be subject to the following:

a. Structural tests as described in MTP 5-2-504.
b. Shock Tests as described in MTP 5-2-506.
c. Vibration tests as described in MTP 5-2-507.
d. Acoustic tests as described in MTP 5-2-508.

These tests may be required as indicated by the type of failure to assess the cause.

6.3 TEST DATA

6.3.1 Inspection

6.3.1.1 Solid Propellant Motors

a. Motor inspection data shall be recorded and collected as described in the motor inspection section of MTP 5-2-500.
b. Record the weight of the test motor, in pounds
c. Record the nozzle throat diameter, at a minimum of three places, in inches.

6.3.1.2 Liquid Propellant Motors

Motor inspection data shall be collected and recorded as described in the prefiring operations section of MTP 5-2-501.

6.3.2 Aerodynamic Load Tests

Aerodynamic load data shall be recorded and collected as described in MTP 5-2-612.

6.3.3 Preparation for Firing

Static guidance and control system data shall be recorded and collected as required by the test director as described in the applicable portions of MTP 5-2-524.

6.3.4 Ambient Firing Tests

6.3.4.1 Solid Propellant Motors

Data shall be recorded and collected as described in the appropriate section of MTP 5-2-500, when applicable.

6.3.4.2 Liquid Propellant Motors

Data shall be recorded and collected as described in the appropriate section of MTP 5-2-501, when applicable.

6.3.4.3 Guidance and Control System

Data shall be recorded and collected as described in the appropriate section of MTP 5-2-524, when applicable.

6.3.5 Extreme Temperature Tests

6.3.5.1 Low Temperature Tests

Data for the missile system under test shall be recorded and collected as described in the applicable portions of MTP 5-2-583.

6.3.5.2 High Temperature Tests

Data for the missile system under test shall be recorded and collected as described in the applicable portions of MTP 5-2-594.

6.3.6 Post Firing Operations

a. Static guidance and control system data shall be recorded and collected, as required by the test director, as described in the applicable portions of MTP 5-2-524.

b. Record all damage as indicated by visual and/or X-ray inspection.

c. Record the missile skin strain as determined from MTP 5-2-587.

6.3.7 Failure Detection

When applicable:

a. Structural data shall be recorded and collected as described in MTP 5-2-504.

b. Shock data shall be recorded and collected as described in MTP 5-2-506.

c. Vibration data shall be recorded and collected as described in MTP 5-2-507.

d. Acoustic data shall be recorded and collected as described in MTP 5-2-508.

6.4 DATA REDUCTION AND PRESENTATION

The data resulting from restrained firing tests shall be presented and analyzed in accordance with the following:

a. Solid propellant motor performance shall be analyzed as described in paragraph 6.4 of MTP 5-2-500.

b. Liquid propellant motor performance shall be analyzed as described in paragraph 6.4 of MTP 5-2-501.

c. Guidance and control system performance shall be analyzed as described in paragraph 6.4 of MTP 5-2-524.

In the event of structural failures, the data obtained by performing structural, shock, vibration and acoustical tests shall be analyzed and presented, as required, as described in MTP 5-2-604.

All data shall be entered in the prepared log book or folder for each missile system fired. It is important that the test log is complete, accurate, and up-to-date as the log may be used for future static, flight, and restrained firing test studies.

Equipment evaluation usually is limited to comparing the actual test results to equipment specifications and the requirements imposed by the intended usage. The test results may also be compared with the results of previous restrained firing and actual flight tests that were conducted on the missile system.

APPENDIX A

RESTRAINED FIRING - ADVANTAGES AND USES

The restrained firing of missile should not be confused with static firings. A comparison of restrained and static firing principles is shown in Figure A-1. The advantages of the restrained firing test, as compared to a "live" missile flight test, are as follows:

a. A restrained firing test is nondestructive, can be repeated when extra motors are available, and usually costs less than a live firing. Therefore, statistical data can be obtained economically.

b. Since restrained firing tests are nondestructive, the missile is available for detailed inspection, other tests, or a subsequent flight test.

c. The instrumentation possibilities are virtually unlimited, whereas, space and weight requirements limit in-flight instrumentation.

d. Restrained firings can be conducted under controlled, simulated, climatic conditions. The environment can be controlled accurately, and practically any combination of restrained firings and simulated climatic environmental conditions can be tested.

The disadvantages of the restrained firing test, as compared to a "live" missile flight test, are as follows:

a. The design of a restrained firing facility is somewhat complicated.

b. Aerodynamic effects are not easily simulated in a restrained firing.

Restrained firings yield qualitative data and most functions of the missile system can be instrumented and monitored. For this reason, a series of tests can be conducted effectively throughout the missile development program. In the early stages of missile development, restrained firings indicate obvious design weaknesses and thereby reduce the number of flight tests that are necessary. A continuous program of periodic restrained firings of missiles, taken from the stockpile during development and production phases of the missile program, will yield valuable information for quality assurance testing, proof testing, and service and shelf life testing.

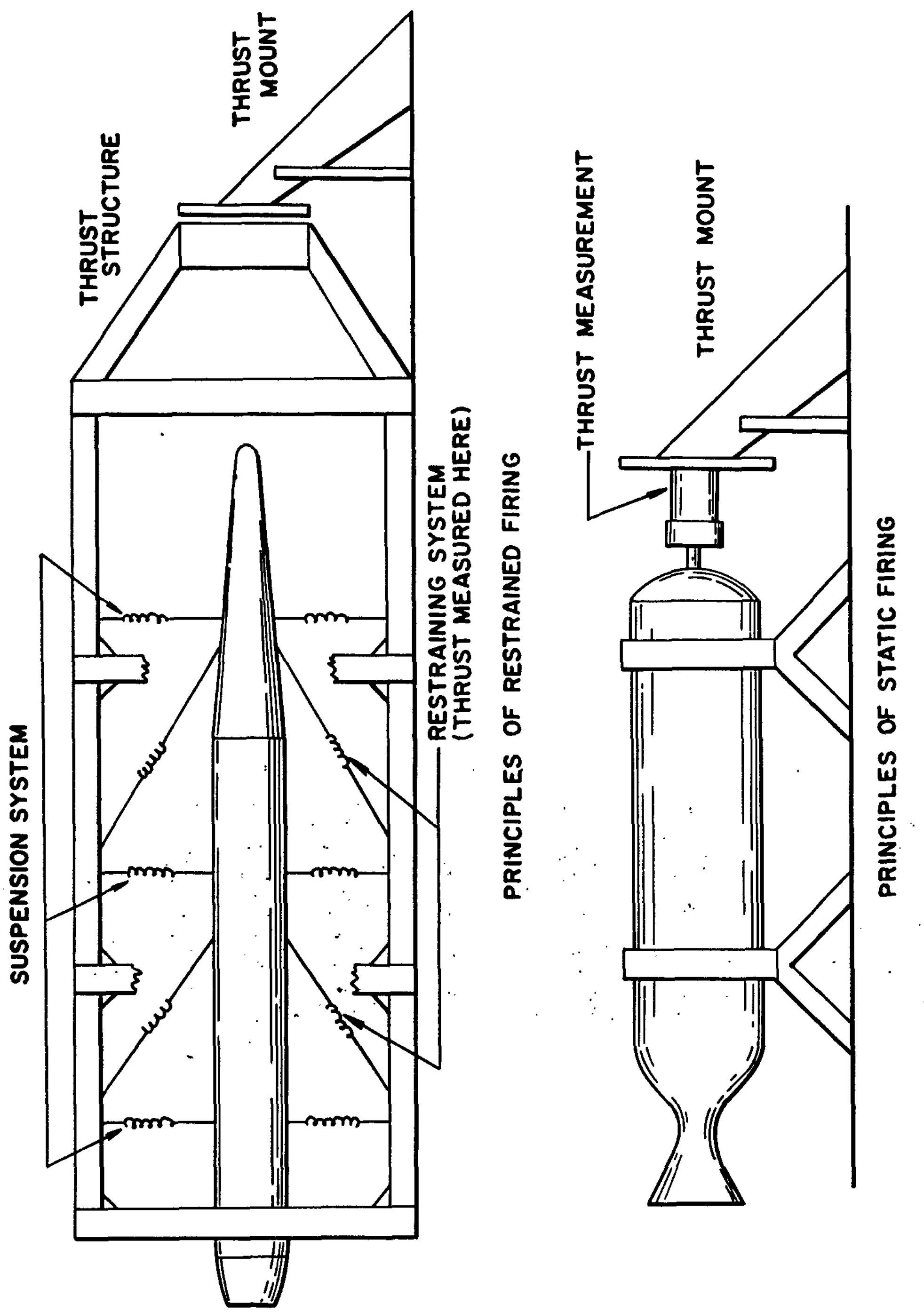

FIGURE A-1 COMPARISON OF THE PRINCIPLE COMPONENTS OF A TYPICAL RESTRAINED AND STATIC FIRING FACILITY

APPENDIX B

RESTRAINED FIRING FACILITY

A. GENERAL CONSIDERATIONS

The restrained firing facility includes that equipment mechanically connected to the missile to hold it captive and to allow it to vibrate freely while the motor is operated. It is important that the resonant frequencies of the restraining system and suspension system are carefully selected so that the restraining facility does not affect missile vibration during the test. The restraining system ties the missile to the restraining structure allowing the missile maximum freedom to move and vibrate. The resonant frequency of the restraining system generally is restricted to less than 5 cps. The restraining system must be fastened to the missile so that possible thrust misalignment will not cause instability, the missile can freely vibrate laterally, the resonant frequency of the missile will not be changed appreciably, and the thrust force is transferred to the structure. The suspension system holds the missile in position. When the missile is restrained and fired vertically, the suspension system and restraining system may be combined. The missile rests on a support and is held in place by the restraining system. This, however, is not always possible, especially when a missile is fired while restrained. As in the case of the restraining system, the suspension system must also allow the missile to move and vibrate freely. The suspension system must not affect the vibration of the missile appreciably, yet it must be strong enough to hold the missile in place. A massive suspension system could create vibration feedback into the missile and/or change the effective missile mass so that unrealistic response frequencies would result.

B. DESIGN CONSIDERATIONS

1. In the design of a restrained firing test facility, as well as during the conduct of the test, safety is of primary importance. Standard safety precautions and special innovations that will ensure the safety of personnel and avoid possible damage to equipment, must be planned and designed into each new test facility or included as a part of the modification of an existing facility.

2. Consideration should be given to building the structure so that it is adjustable, moveable, and capable of being modified to permit testing of several types of missile systems. It may be possible to design all of the tiedown points so they can be moved and adjusted easily (see Figure B-1). Consider bolting the cross bracing and suspension tiedowns to supporting beams of the structure using the same size bolts and bolt pattern.

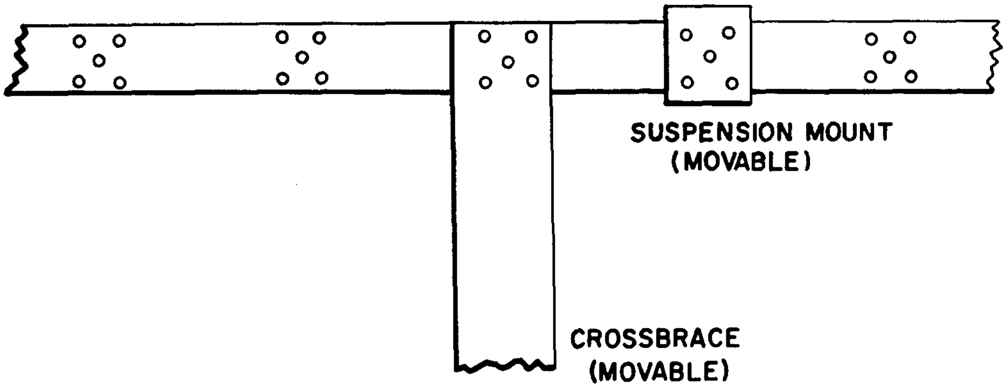

FIGURE B-1. A TYPICAL ADJUSTABLE SUSPENSION TIEDOWN

3. The testing structure should be strong enough to transmit the thrust force of the missile to the thrust mount and should provide for ample working space around the missile. For economy, the massiveness of the structure should be minimized.

C. RESTRAINING AND SUSPENSION SYSTEMS CONSIDERATIONS

1. The restraining system within the structure is influenced by the overall size and weight of the missile system, amount of thrust developed by the missile motor, horizontal or vertical firing position of the missile, resonant frequency of the missile and of the motor thrust force, and the strength of the missile structure. The calculation relating to the resonant frequency of the restraining system is simplified by considering the restraining system and the missile in combination as a single spring-mass system. Knowing the resonant frequency of the missile, choose a frequency for the restraining system-missile combination that will not affect the missile vibrations. Using this resonant frequency, the spring constant of the restraining system can be determined. A set of springs, a hydraulic system, rubber pads, etc., may be obtained that meet this spring constant specification.

2. Damping must be added to the restraining system if the missile is to be allowed to move forward or upward. The motor thrust and the inertia force builds rapidly causing an instantaneous overload on the restraining system. Vibration will occur that may affect the accuracy of test data as the thrust and restraining forces equalize. Air or oil flow shock absorbers are the most common methods of damping the system. The restrained firing system shown in Figure B-2 utilizes the nonlinearity of the compressibility of air damping.

3. The restraining system must be fastened to the missile so that the thrust force is transmitted to the structure without appreciably affecting the missile's vibration and stabilization. Missile systems, by design, are relatively light and, therefore, any brackets fastened to the

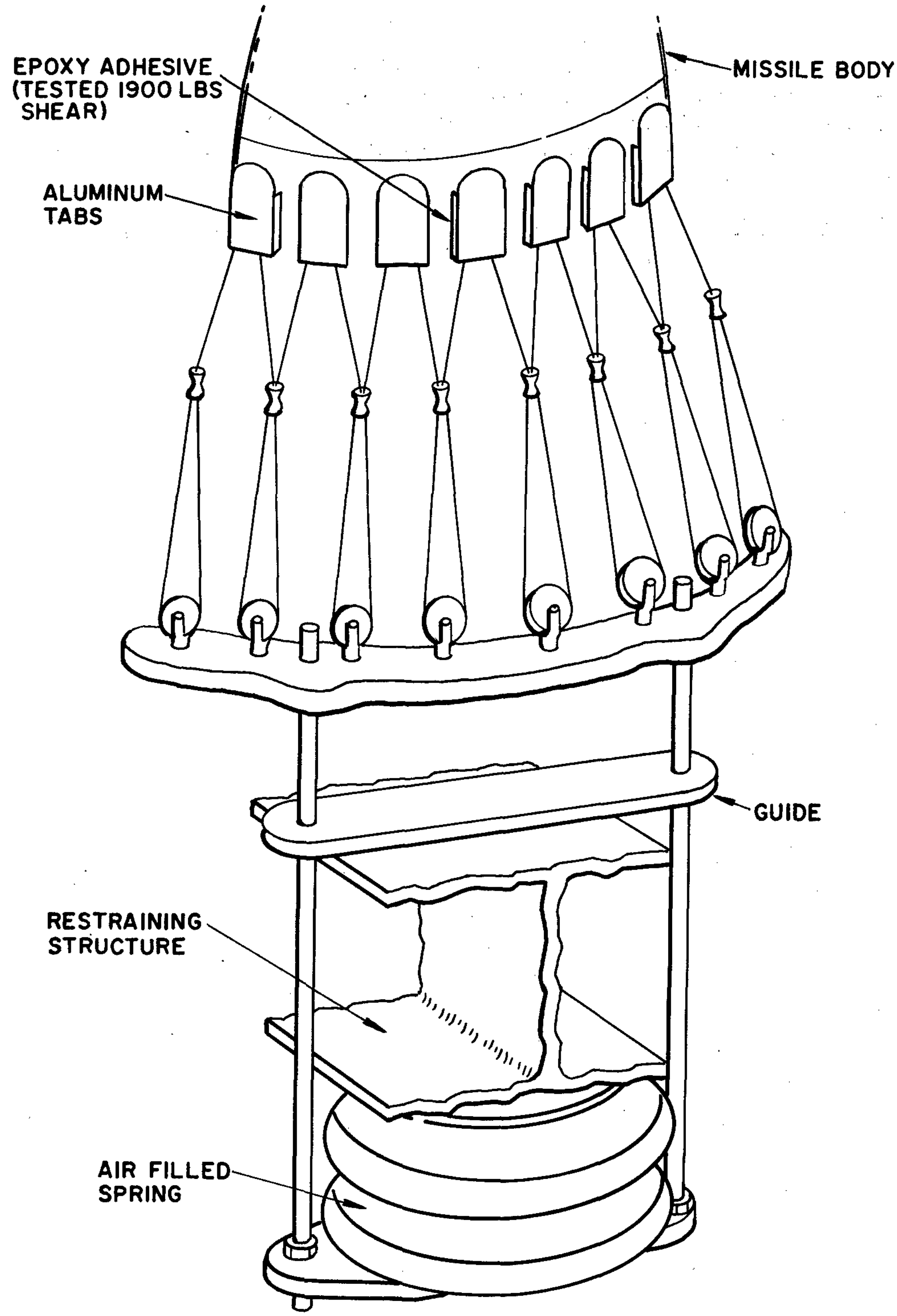

FIGURE B-2. A TYPICAL RESTRAINING SYSTEM

missile should be light, yet strong enough to transfer the thrust load. A large number of smaller brackets fastened to the missile structure at its strongest points is a satisfactory method of securing the restraining system. Stopping a missile's forward motion requires a force equal to the thrust plus the inertia of the missile.

4. The suspension system requirements are similar to those of the restraining system (paragraphs 1, 2, and 3).

APPENDIX C

FIRING TEST FACILITIES AND EQUIPMENT

A. FIRING TEST FACILITIES AND EQUIPMENT

Engine testing facilities are equipped with thrust bulkheads which are sufficiently massive to resist the motor thrust and are as nonresonant as possible. The general practice is to construct thrust bulkheads of concrete with embedded steel rails or faced with steel plates to provide a means of connecting thrust measuring devices.

Some type of flame deflector shall be required to prevent excessive damage to the test facility due to flame erosion. The flame deflectors may be flat or dished open surfaces made from concrete or steel and may be either water cooled, or not, depending upon the thrust rating, firing duration, elevation of the motor exhaust above the deflector, and exhaust gas composition. Some deflectors are of the water-cooled elbow design and deflect the exhaust gases a full 90 degrees. Elbow deflectors generally require a large amount of cooling water and are not considered economical, especially where process water is scarce. The facility shall have ample water, not only for cooling purposes but for fire protection as well. The fire system shall be equipped for automatic as well as emergency manual activation.

Control centers at modern facilities are usually air conditioned because of the large amount of electronic equipment which they contain. Temperature control is essential for high accuracy as well as for personnel comfort.

The static firing test facility shall contain an automatic control console capable of turning on all instrumentation at a programmed time, commencing photographic coverage at X-10, firing the engine, and shorting the firing circuit. These events shall be completely automatic but manual control shall be possible at any time in the event of malfunction. Indirect vision through mirrors and/or closed circuit television for test observation is common practice and two-way voice communication between the control center and test stand is considered essential.

Data systems shall be connected through patch panels at both the transducer and recorder ends to provide flexibility in test setups. On-site oscillogram processing shall be provided for rapid data reduction.

Supporting facilities such as machine shops, propellant storage, and supply rooms are required to prevent delays in test operations.

Ample electrical power shall be provided for both normal operation and excess load requirements.

Process water shall be ample for fire fighting and decontamination purposes in addition to all other requirements. Permanently connected and automatically controlled fog or spray nozzle systems are considered essential,

as well as hand operated chemical extinguishers. Facilities shall provide remotely controlled, automatic, chemical fire fighting systems.

When a liquid propellant restrained test is conducted on a complete missile, the propellant tanks and gas tank of the missile will be used to supply propellants and high pressure gas. A set of propellant tanks of the same capacity as those of the missile shall be mounted in the test stand tower over the engine. These tanks shall be charged by the test stand's propellant storage tanks which shall be of sufficient capacity to supply propellants for several firings on the motor. It is desirable that these storage tanks be so located that it will be possible to fill the firing tanks by gravity flow.

A supply of high pressure inert gas such as nitrogen is needed for blanketing propellant tanks and for operating pneumatic valves.

B. PROPULSION SYSTEM COMPONENTS TEST FACILITIES AND EQUIPMENT

These test facilities and equipment consist of the pneumatic, hydraulic, and electrical test facilities. The pneumatic and hydraulic test facilities are frequently used to calibrate flow meters and to set regulators. Accuracy of component testing is dependent upon the accurate calibration of the equipment contained in the test benches. Calibration of all measuring and recording instruments by a laboratory equipped with primary standards must be accomplished at regular intervals.

1. Pneumatic Test Facilities and Equipment

The major facility for pneumatic component testing is a flow bench which supplies a centralized distribution, regulation, and flow control point for high pressure gas, supplied by a large volume, high pressure, cascade system. Pressure, volume, and type of gas are determined by specifications applicable to the systems to be tested. For convenience and efficient operation, the flow bench shall be divided into a high flow system and a low flow system. Incorporated within each flow system shall be regulators to control pressure over the entire available range, flow tubes (straightening vanes), and differential pressure transducers, and flow meters for measuring flow.

The pneumatic flow bench shall be a conveniently arranged assemblage of the apparatus required for accurately and efficiently determining the operating characteristics, calibration, reliability, and life of pneumatic components of missile systems. The bench shall contain all necessary instrumentation for controlling and recording pneumatic pressures and flows.

2. Hydraulic Test Facilities and Equipment

The hydraulic flow bench used for the testing of missile system hydraulic components provides a centralized controlled source of liquid flow and pressure.

For convenient and efficient operation, the hydraulic flow bench

shall be separated into an oil flow system and water flow system. The range of flows and pressures must be known.

Incorporated in the bench shall be filters, flow meters, heat exchangers, weigh tanks, timing clock, antifoaming storage tank, and all instrumentation for controlling and recording hydraulic pressures and flows.

3. Electrical Test Facilities and Equipment

The electrical test bench provides a centralized distribution subpanel for the various types of electrical power that are required in evaluating and testing propulsion system electrical components.

The bench shall provide complete instrumentation for measuring and recording the performance of electrically driven rotary components, relays, solenoids, switches, instruments, signal devices, electro-mechanical servo-mechanisms, and similar missile equipment.

APPENDIX D

INSTRUMENTATION

Specific instrumentation requirements are dependent upon the motor being fired (solid or liquid propellant), the firing facility and restraining facility design, the guidance and control system design and the specific test objectives for which the test is being conducted.

Listed below are the basic requirements and how they are accomplished:

A. THRUST

Thrust is usually not measured in restrained firing tests.

NOTE: When thrust is to be measured the general practice is to record data both on magnetic tape and oscillographs. The oscillograph provides ready information while the tape (analog or digital) can be played into automatic data reduction systems.

B. PRESSURE

Motor chamber pressure is usually measured by attaching a calibrated transducer to a port in the head or aft end of the motor case by using a short length of stainless tubing. The transducer output is amplified and recorded in the same manner as the thrust data.

C. TEMPERATURE

Temperature is usually measured with appropriate thermocouples and recorded on strip-chart recorders.

WARNING

Care shall be taken when thermocouples are installed in the solid propellant grain or liquid propellant to insure that there is no possibility of high voltage or stray current being applied to the thermocouple. Such an accident could result in an unexpected ignition since the thermocouple would become a resistance heater.

D. GUIDANCE AND CONTROL SYSTEM

An inertial monitor capable of recording the ability of the missile guidance and control system to accurately follow the programmed inputs, is required.

E. PHOTOGRAPHIC COVERAGE

Motion picture coverage shall be taken at frame rates of 1000 frames per second so that any event leading to a possible catastropic failure, such as leaks, burn-through or guidance and control system failure are recorded. Also, a careful examination of the exhaust flame can locate evidence of abnormal performance, and pictures of the rockets reaction to guidance and control commands will act as a backup to the inertial monitor. Normally at least two cameras are positioned at different angles to ensure that complete coverage of the motor, jet and nozzle, and entire exhaust flame is obtained.

F. PHOTOSTRESS MEASUREMENTS

Stress incurred in the structural body of the missile system shall be determined by using the appropriate instrument, as described in MTP 5-2-587:

1. Polariscopes
2. Optical Compensators
3. Large Field Meter
4. Small Field Meter
5. Oblique Incidence Meter

APPENDIX E

FAILURE

Failure detection is one of the most perplexing problems of the restrained firing test. Usually, it is not difficult to instrument a test to determine an area of malfunction, such as the guidance system or flight control system, but often a difficulty lies in determining the specific component part that failed. There is no set procedure for failure investigation or trouble-shooting, but all available pertinent drawings, system specification documents, and operating instructions, as well as good engineering practices, should be used.

A. FAILURE CLASSIFICATION

Failure can be classified as follows:

1. Intermittent - an intermittent failure is one that occurs during the test but disappears when the equipment returns to normal operation after the causitive influence is removed.

2. Catastrophic - a catastrophic failure is one which results in a failure of some component of the equipment and can be detected by inspection after the test. At times X-ray and metallurgical inspections may be required.

B. CAUSES OF FAILURES

Restrained firing tests produce four effects that may cause failure of a missile component. These are:

1. Shock - Thrust of a rocket motor generally builds up rapidly after ignition and the missile experiences a mechanical shock or a series of shocks that can cause intermittent and/or catastrophic failures. Investigation of failures occurring during this portion of the test may be accomplished by conducting shock tests in accordance with the procedures described in MTP 5-2-506.

2. Mechanical Stress - Motor thrust creates mechanical stress in the missile structure. Failures considered to be caused by the thrust load may be investigated by conducting structural loading tests as described in MTP 5-2-504.

3. Vibration - Motor induced vibrations may cause intermittent and/or catastrophic failures. Investigation of the failures considered to be caused by vibration may be accomplished by conducting applicable tests, as described in MTP 5-2-507.

4. Acoustic - The acoustic effects experienced by the missile during a restrained firing test usually are of a high level and may cause failures. Detailed acoustic test procedures are described in MTP 5-2-508.